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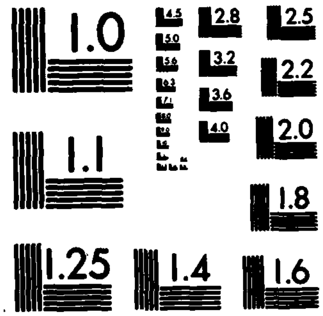

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EXPANDING THE PERMANENT FILE DIRECTORY ON THE CDC NOS/BE OPERATING SYSTEMS

by

Roger L. Yearick

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Computation, Mathematics and Logistics Department

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Expanding the Permanent File Directory on the CDC NOS/BE Operating System

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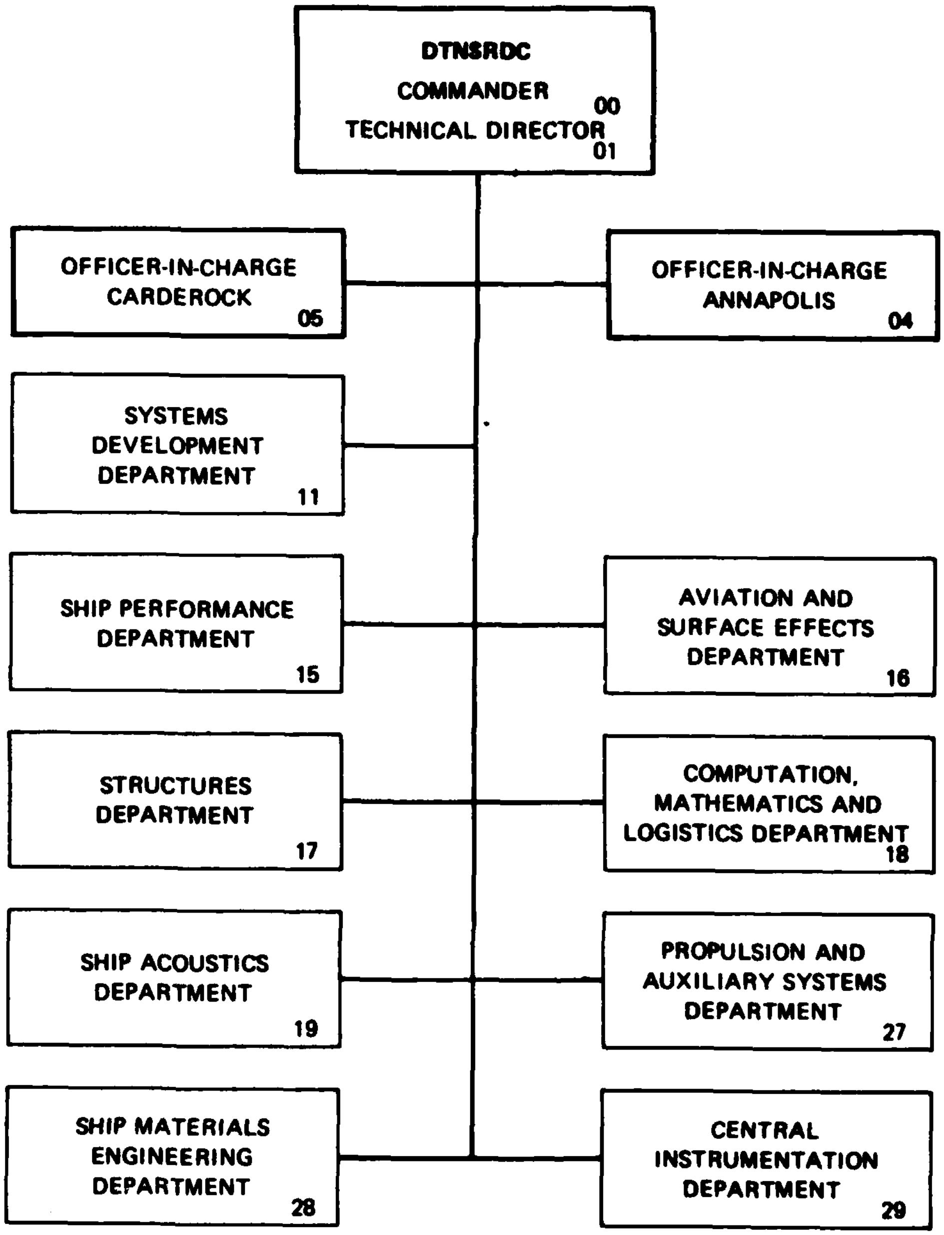

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This report documents a solution to the limited size of the permanent file base on the Control Data Corporation computers running the NOS/BE operating system. The CDC permanent file concept, and modifications made to the standard operating system are explained. These modifications have increased the number of permanent files allowed for the default permanent file set, and also improved the response time for all permanent file functions.

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LIST OF ABBREVIATIONS

CDC	Control Data Corporation
CMR	Central Memory Resident
DTNSRDC	David W. Taylor Naval Ship Research and Development Center
EST	Equipment Status Table
ID	User Identification
MD	Multiple Directory
MST	Mounted Set Table
NOS/BE	Network Operating System/Batch Environment
PFC	Permanent File Catalog
PFD	Permanent File Directory
PP	Peripheral Processor
PRU	Physical Record Unit
RB	Record Block
RMS	Rotating Mass Storage

ABSTRACT

This report documents a solution to the limited size of the permanent file base on the Control Data Corporation (CDC) computers running the NOS/BE operating system. The CDC permanent file concept, and modifications made to the standard operating system are explained. These modifications have increased the number of permanent files allowed for the default permanent file set, and also improved the response time for all permanent file functions.

ADMINISTRATIVE INFORMATION

The work described in this report was performed in the Systems Software Group (Code 1892.3) of the Computation, Mathematics, and Logistics Department, David W. Taylor Naval Ship Research and Development Center (DTNSRDC) under the sponsorship of the DTNSRDC Computer Center (Code 189).

INTRODUCTION

Two files are used for referencing permanent file names and locations on disk. The Permanent File Directory (PFD) is a fixed length file that contains a fixed length entry for each permanent file/ID pair in the system. The PFD file is divided into subdirectories, so the entire PFD need not be searched to find a desired permanent file. Each file in the system "belongs" to a particular subdirectory based upon a hashing algorithm. Standard NOS/BE uses nine characters of the user ID as a hashing algorithm. At DTNSRDC we use nine characters of the permanent file name. The PFD contains a pointer to the Permanent File Catalog (PFC). The PFC is a fixed length file with variable length entries that contain actual disk locations of files.

When a particular file is needed by a user, the permanent file routine finds the file by hashing to the beginning of the subdirectory the file resides in, then searches the PFD sequentially from this point. When the file's PFD entry is found, the PFC pointer is determined, and the permanent file routine reads the PFC entry to find the file's disk location.

The size of the PFD is determined by the number of files defined at initialization. This number cannot exceed 16384 (decimal). The number of files also determines the

number of subdirectories and size of the subdirectories. When all entries in a subdirectory are in use, the next file to hash to that subdirectory will use the next empty entry in the PFD, which is really in another subdirectory. This is a condition called overflow. Thus, an overflowed subdirectory uses entries in other subsequent subdirectories. This overflowed subdirectory is full, and there is no room for entries that belong there. In time, the hashing algorithm to find files in the PFD is useless because the entire directory is being searched due to overflow.

OBJECTIVES

The objective of this project was to increase the PFD size to allow more than 16000 permanent file PFD entries and to eliminate subdirectory overflow, while keeping any changes transparent to the computer user. A minimum amount of code changes was desirable to facilitate upgrading to newer levels of the operating system.

SOLUTION

One solution to the directory problems considered but rejected was increasing the maximum size of the directory. This was rejected due to the extensive modifications required to the permanent file PP routines, which have a limited amount of space available.

Another rejected solution was using more than one device set for default permanent files. Since files are written to disk before being cataloged, this approach would necessitate knowing the correct device set residence of a file before the file was opened. This would require control card changes which would not be transparent to the user, or would necessitate copying a file created on the "wrong" set to another set to maintain its proper residence.

The solution chosen to solve our problems was to create multiple PFD/PFC files called Multiple Directories (MD) for the permanent file default set. Each MD is on a separate disk pack. User files are distributed among the MD's by hashing of the user Identification (ID). Thus, the directory entries for all files of a particular ID reside on the same MD.

In the MD set we maintain one set of disks, but use more than one directory to locate the files stored on these disks. Up to ten directories can be defined, effectively increasing the number of PFD entries to 160,000 entries.

MD CONFIGURATION MODIFICATIONS

A device set is a group of rotating mass storage (RMS) devices. In the standard device set, there is a master device that contains the PFD/PFC files and related device set tables, and a variable number of member RMS devices (See figure 1). In the multiple PFD/PFC device set the secondary directory PFD/PFC files reside on set member RMS devices (See figure 2). A separate RMS device is required for each

PF SET ORGANIZATION

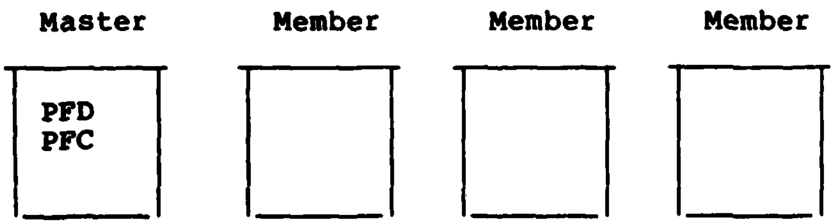

FIGURE 1

PF SET ORGANIZATION WITH MULTIPLE DIRECTORY

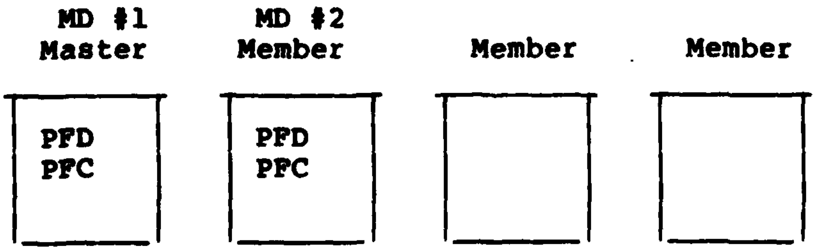

FIGURE 2

directory defined. The number of multiple directories in use is defined in comdeck IPARAMS, with the symbol IP.NMD equated to the number required. The default for IP.NMD is one. In comdeck PPSYS, word 72B (P.NMD) in central memory is defined as the pointer to the number of MDs defined.

Separate device sets for system files, queue files, scratch files, and permanent files can be defined in the Central Memory Resident (CMR) routine. The pointers to each directory for these sets are maintained in the Mounted Set Table (MST) in CMR. Every configured set has an entry in the MST (See figure 3).

Mounted Set Table (MST)
Standard Device Set Configuration

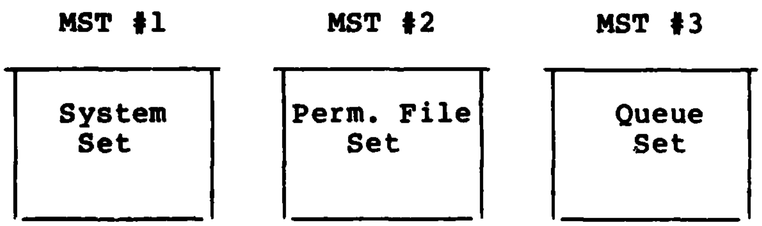

FIGURE 3

For a multiple directory set, each MD has a separate MST entry (See figure 4). Only the default permanent file set may have multiple directories defined. When configuring a MD set, all multiple directories must be in succession, with no other intervening sets defined in the Equipment Status Table (EST). Figure 5 illustrates an illegal configuration. The Queue Set MST is between the Permanent File Set Multiple Directory MSTs. IP.NMD is checked against the EST configuration to ensure the proper number of MD's are configured. The first six characters of each MD setname configured must be identical. The seventh character is used to uniquely identify the secondary MD's (i.e., SN=SYSSET for MD#1, SN=SYSSET1 for MD#2, up to SN=SYSSET9 for MD#10)

On a multi-mainframe system that shares default permanent files, a separate RMS controller is required for each multiple directory defined. Inter-locked stack requests are used to prevent simultaneous mainframe directory access.

Mounted Set Table (MST)
Device Set Configuration with MD

MST #1	MST #2	MST #3	MST#4
System Set	Perm. File Set MD #1	Perm. File Set MD #2	Queue Set

FIGURE 4

Mounted Set Table (MST)
ILLEGAL Device Set Configuration with MD

MST #1	MST #2	MST #3	MST #4
System Set	Perm. File Set MD #1	Queue Set	Perm. File Set MD #2

FIGURE 5

MD DEADSTART MODIFICATIONS

When initializing a configured multiple directory set, each MD must be initialized. (Type ´SYSSET,I´ and ´SYSSET1,I´ for a two MD system at deadstart equipment change time.) GENDJ has been modified to generate ADDSET control cards to add each MD as a separate master, and also as a member of the permanent file default set. For initialization of an MD, ADDSET(ADS) creates the PFD/PFC files and pack label on the MD device as a master, and then adds the device as a member of the default permanent file set. GENDJ then notifies the operator when deadstart is complete. A normal deadstart is then required for system operation.

All subsequent deadstarts, normal or recovery type, are unchanged. At deadstart time RECOVER and TMT validate all PFD/PFC files for the multiple directories and build a Device Allocation Map (DAM) table which contains the free and available space for each member of the set. This table is then written to the master device of the default permanent file set, which is MD#1. TMT checks the current configuration for the number of multiple directories configured, and then rewrites P.NMD with this value. Mount (MNT), at deadstart time, runs in a Master/Member mode on the secondary multiple directories, mounting them as separate masters, creating an MST entry for each MD which contains the pointers to the PFD/PFC files, and also mounting them as members of the default permanent file set.

MD OPERATION MODIFICATIONS

On our standard operating system we have incorporated some modifications to improve permanent file efficiency. The multiple directory set requires some of these changes. Permanent files on the PF default set are hashed by permanent file name (rather than ID) to a subdirectory in the PFD. This was done to prevent subdirectory overflow, because the ID name assignment used at DTNSRDC does not provide a good file distribution. A user's private device set is still hashed by ID name. On a rename of a file by permanent file name, we modified PFR to move the PFD entry if the renamed file hashed to a different subdirectory. The standard NOS/BE system does not move the directory entry, even when a rename results in the file belonging to a different subdirectory.

In the multiple directory PF set the permanent files are hashed by ID name to the proper directory, then to the subdirectory by permanent file name. The number of multiple directories in use is defined in a central memory word in low core (P.NMD). The hash routine uses this value for the number of hash points to find a file's proper directory. The directory number is then biased by the default permanent file set MST ordinal to obtain the multiple directory MST ordinal for the file. Routines using hash code do not require re-assembly for different system configurations. These hashing modifications are in comdeck PFHASH, which is used by attach(PFA), catalog(PFC), load(LPF), extend(EPF), and rename(PFR).

The RENAME control card is the only control card with changes visible to the user. Since a rename by ID might require moving PFD and PFC entries to a new MD, rename by ID

was not allowed. A procedure was created for users to rename a file's ID. This procedure copies the file, re-catalogs the file with the new ID, and purges the entry for the old ID.

The AUDIT program used by DTNSRDC is locally written. It reads the PFD/PFC files directly. With a multiple directory set, AUDIT need access only one of the PFD/PFC files when performing an audit by ID. This means that with a two MD system, AUDIT need search through only approximately one-half the permanent file base. On a full system audit all multiple directories are processed but separate PFD/PFC statistics are provided. A system audit may also be done on individual multiple directories by specifying the MD setname on the AUDIT control card.

The DUMPF utility, used for dumping permanent files, was modified to process all directories with one DUMPF control card. Individual multiple directories may also be dumped separately by specifying the MD setname on the DUMPF control card. This individual directory dump feature halved the time required to do a full permanent file dump on our 6600/6700 multi-mainframe system.

The TRANSPF utility, used for changing file residence when removing a set member device, was modified to process all MDs within the permanent file default set. The FS and TS parameters must be the master multiple directory(MD#1), and the FM parameter cannot be an MD.

DELSET(DLM), used to delete a member from a set, was modified to check all MDs for permanent file residence on the device to be deleted, and also disallow a MD delete.

RELABEL, used for adding flaws to a device or writing a new label, was modified to add flaws to an MD device as a member of the default PF set, and not rewrite the MD device label.

SETNAME and REQUEST control cards specifying a particular MD other than MD#1 (i.e. - 'SETNAME,SYSSET1.' or 'REQUEST,LFN,*PF,SN=SYSSET2.'), use the default permanent file set master (MD#1). MD#1 contains the DAM, Set Member Table (SMT), and flaw tables for the MD device set. When RB file space is needed or when a file overflows a RMS device, MD#1 device set tables are used to allocate mass storage space.

MD INSTALLATION AT DTNSRDC

The CDC 6400 at DTNSRDC was the first system to use multiple directories. A two MD set was defined for this system March 3, 1982. On April 4, 1982 the same configuration was installed on the CYBER74. The CDC 6600 and CDC 6700 share permanent files, and a two MD set was installed on these mainframes August 19, 1982. The multiple directory code was written and installed on all mainframes at Level 508 release of the NOS/BE operating system. Subsequently, all systems were up-graded to the Level 552 release of NOS/BE. Multiple directory code was enhanced and up-graded at the same time the system was up-graded to Level 552. This installation was complete on October 25, 1982.

When DTNSRDC acquired a CDC CYBER 170-176, NOS/BE Level 552 with MD code was installed on this system. It became operational June 13,1983.

The CDC 6600/6700 systems were retired and replaced by the CDC CYBER 170-750 system in December, 1983. Level 552 NOS/BE and MD code were installed and operational on this system December 9, 1983.

MD installation involved changes to 32 system routines with approximately 2100 lines of modified code (See figure 6).

NOS/BE MODIFICATIONS FOR MD			
Routine	# of Lines Modified	Routine	# of Lines Modified
ADS	46	PFCCP	2
CMR	90	PFCELLS	5
CON	5	PFHASH	60
DECKALL	38	PFMESS	5
DLM	90	PFR	12
DUMPF	184	PPSYS	2
FASTAUD	318	PREAMB	2
GENDJ	119	RECOVER	350
IPARAMS	2	RELABEL	55
IRCP	109	REQ	11
LBL	55	TRANSPF	220
LDQ	15	TMT	84
LPF	12	1AJ	21
MNT	100	1PC	16
OUX	26	1PK	13
PFC	6	3DO	43

FIGURE 6

CONCLUSIONS

The CDC 6600/6700 shared permanent file base had the serious problems that multiple directory was designed to solve. The PFD size limit had been reached, and in the ideal case, 15 of 61 subdirectories had overflowed (See figure 7). The ideal case occurs immediately following reloading of the complete permanent file base, which is rarely done. Since overflow of one subdirectory adversely affects the following subdirectory, the actual case was much worse. We had 58 of 61 subdirectories overflowed with little space

in the remaining ones.

With a two MD permanent file set, there are no overflow problems, and the number of available PFD entries has doubled (See figure 8). The batch and interactive response times to permanent file commands has significantly improved (See figures 9 and 10). With the improved permanent file function time, faster dump, audit, and load time, and an increase in allowable Permanent File Directory entries, there has been an overall improvement in the CDC NOS/BE systems performance.

66/6700 PERMANENT FILE BASE

Number of directories = 1 Number of sub-directories = 61

subd number	number of PFs	overflow	subd number	number of PFs	overflow
1	187	no	31	282	yes
2	187	no	32	229	no
3	241	no	33	300	yes
4	213	no	34	296	yes
5	279	yes	35	227	no
6	205	no	36	257	yes
7	197	no	37	245	no
8	241	no	38	289	yes
9	217	no	39	230	no
10	233	no	40	341	yes
11	229	no	41	259	yes
12	333	yes	42	232	no
13	242	no	43	240	no
14	214	no	44	226	no
15	243	no	45	200	no
16	214	no	46	246	no
17	250	no	47	234	no
18	218	no	48	203	no
19	214	no	49	211	no
20	229	no	50	282	yes
21	251	no	51	191	no
22	235	no	52	201	no
23	203	no	53	219	no
24	244	no	54	209	no
25	287	yes	55	245	no
26	269	yes	56	200	no
27	276	yes	57	239	no
28	260	yes	58	292	yes
29	247	no	59	210	no
30	240	no	60	178	no
			61	230	no

Total number of PFD entries = 14570
Overflowed sub-directories = 15

FIGURE 7

66/6700 PERMANENT FILE BASE

Number of directories = 2 Number of sub-directories = 61

subd number	number of PFs dir#1	number of PFs dir#2	overflow	subd number	number of PFs dir#1	number of PFs dir#2	overflow
1	72	115	no	31	124	158	no
2	93	94	no	32	121	108	no
3	111	130	no	33	180	120	no
4	103	110	no	34	135	161	no
5	117	162	no	35	108	119	no
6	86	119	no	36	112	145	no
7	86	111	no	37	107	138	no
8	121	120	no	38	135	154	no
9	94	123	no	39	105	125	no
10	117	116	no	40	230	111	no
11	95	134	no	41	125	134	no
12	169	164	no	42	136	96	no
13	110	132	no	43	126	114	no
14	95	148	no	44	103	123	no
15	106	137	no	45	100	100	no
16	102	112	no	46	123	123	no
17	133	117	no	47	99	135	no
18	114	104	no	48	94	109	no
19	110	104	no	49	94	117	no
20	111	118	no	50	139	143	no
21	109	142	no	51	77	114	no
22	120	115	no	52	94	107	no
23	105	98	no	53	100	119	no
24	119	125	no	54	100	109	no
25	130	157	no	55	129	116	no
26	104	165	no	56	93	107	no
27	143	133	no	57	98	141	no
28	125	135	no	58	161	131	no
29	127	120	no	59	126	84	no
30	119	121	no	60	100	78	no
				61	102	128	no

Total number of PFD entries for MD # 1 = 7022
Total number of PFD entries for MD # 2 = 7548
Overflowed sub-directories = 0

FIGURE 8

PF FUNCTION COMPLETION RATES (PRIME TIME)						
	MFA ----- Average Completion Time in Seconds			MFB ----- Average Completion Time in Seconds		
PF Function	Before MD	After MD	Improvement	Before MD	After MD	Improvement
Attach	2.2	1.2	+45%	2.4	1.2	+50%
Catalog	5.4	2.3	+57%	7.3	3.2	+56%
Purge	1.9	1.2	+37%	2.5	1.3	+48%
Charge	3.7	2.6	+30%	4.9	4.1	+16%

FIGURE 9

PF COMMANDS COMPLETED WITHIN 1 SECOND (PRIME TIME)						
	MFA ----- Percent Completed Within 1 Second			MFB ----- Percent Completed Within 1 Second		
PF Function	Before MD	After MD	Improvement	Before MD	After MD	Improvement
Attach	76.4	96.0	+19.6%	67.2	95.0	+27.8%
Catalog	33.0	69.9	+36.9%	22.1	54.9	+32.8%
Purge	75.1	89.8	+14.7%	65.5	90.2	+24.7%

FIGURE 10

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